DCS Satellite Use Concept Validation Project

Beau Backus
NOAA/NESDIS

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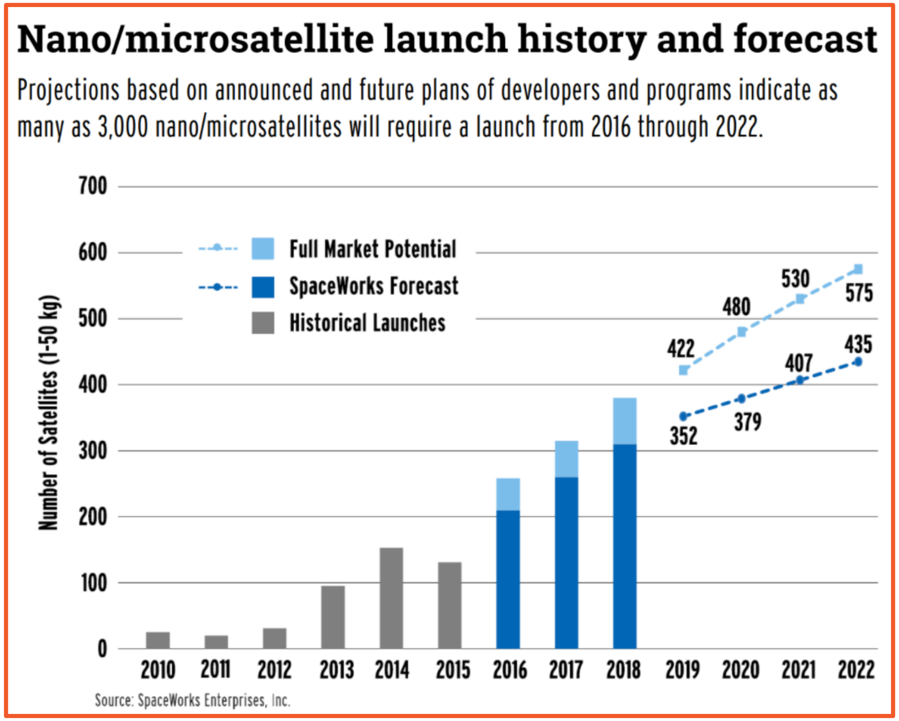
Issue: Growing Demand for 400 MHz

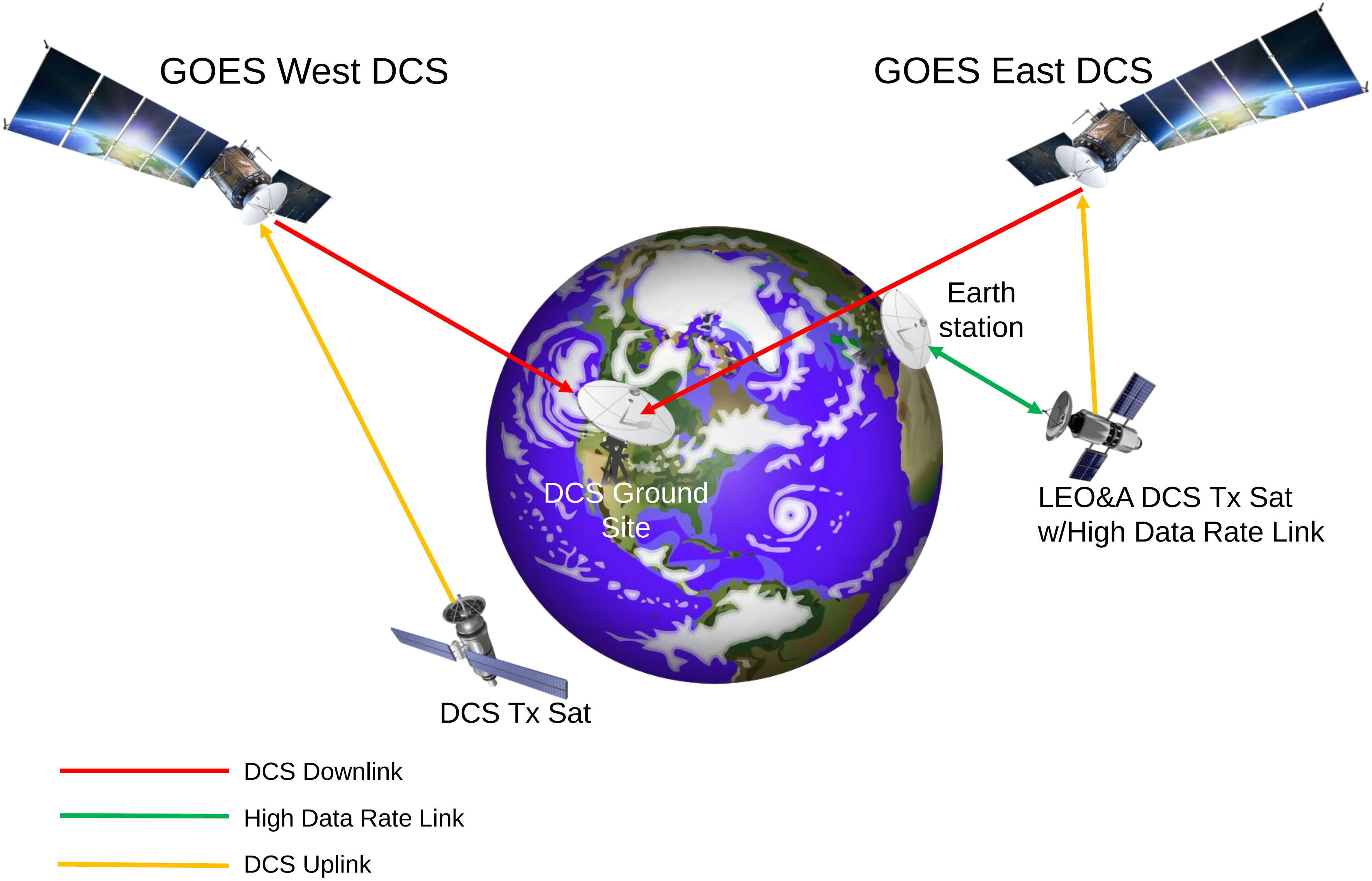
- DCS Transmitters, located throughout the United States & Protectorates (US&P) as well as many other countries, use the 401 MHz band to uplink to the DCPR on GOES (and others) satellites in geosynchronous and non-geosynchronous orbits.
- Satellites are also allocated to use this band (space-to-Earth) for space operations purposes.
  - Typically, these satellites transmit in all directions relatively equally and thus also radiate in direction of GOES and other DCS receiving satellites.
  - This energy, aggregated across multiples of these satellites (even multiples of constellations) is expected to become a significant source of RFI to the DCS system in time.



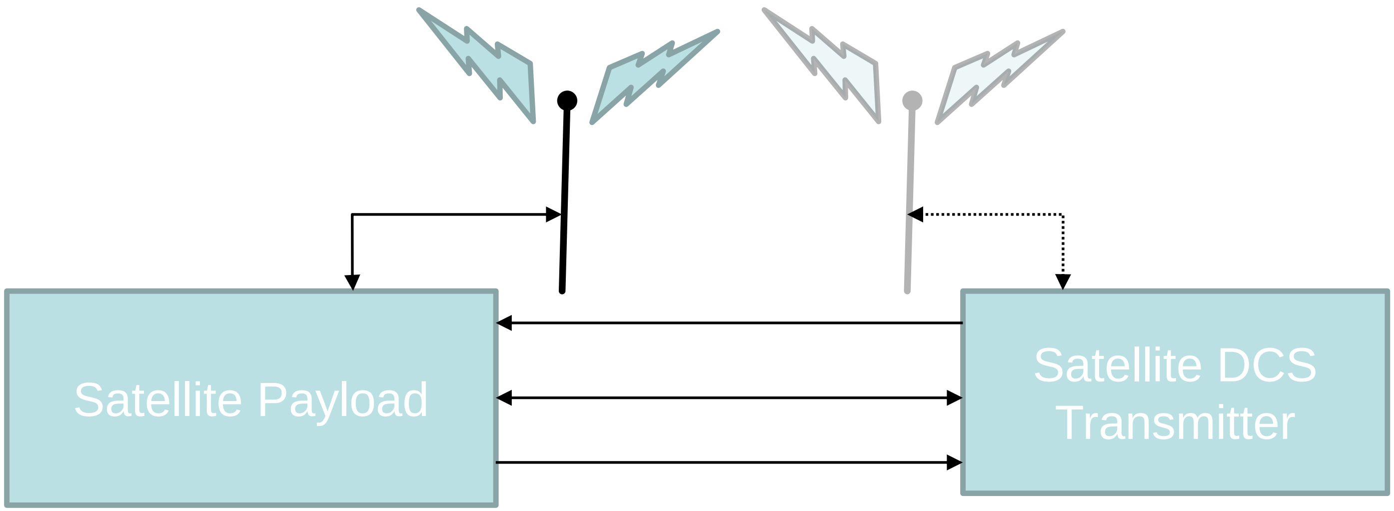
Concept: Use of DCS for Satellite Telemetry, Tracking and Small Data

- Concept of Satellite DCS Use is to enable satellites the ability and authorization to use DCS as a low-rate (300 & 1200 bps) interface for low data rate Launch, Early Orbit, and Anomaly (LEO&A) and/or payload communications and thereby make them a coordinated part of DCS and decrease the risk of RFI to the DCS.
    - The data flow will be from the satellite using DCS to the DCPR on GOES and then through the DCS information distribution process to the identified satellite mission operations center.
    - Should the satellite also require higher data rates, the satellite will use an alternate data link path and frequency.

Notional Architecture Concept



Satellite Connectivity to DCS



- The DCS transmitter on board the S/C will use GPS from the S/C.
- System will turn on for the periods allocated by DCS system
- Analysis being done to account for possible doppler shift to other DCS receivers
- Interface definitions are being worked between the S/C host and the DCS board design team

Tiger Team Review of Concept

- Team met 11 times starting on September 21, 2017,
  - Several additional splinter meetings to work specific identified problems
- Overarching goal to identify any “show stopper” issues that negates further investigation of the satellite DCS use concept
- No issues were found to be “show stoppers”
- Some issues are either challenging or a significant change in DCS usage
- NOAA OGC is of the opinion that this activity demonstrates NOAA’s ongoing efforts to use spectrum efficiently and share where-ever possible

Tiger Team Identified Issues

- Doppler Shift
  - Compensating for the Doppler shift is necessary to close link with the GOES DCS receiver
  - Effect may lead to different frequencies at different DCS receivers.
- Transmission Power
  - Excessive power can be a source of interference to other DCS satellite receivers, however sufficient power is needed to close link
- Loading Factor
  - DCS international band was identified as being both appropriate for use and significantly available
- International Coordination
  - Satellite DCS transmitter, by nature of the antenna it must use, will also be radiating in the directions of other DCS satellite receivers
  - International channels would need to be upgraded to support 300 and/or 1200 baud data rates
  - Validation testing will be done in NOAA DCS testing channels.

Tiger Team Identified Issues *(cont.)*

- Extent of Use Permitted
  - Federal and University organizations are able to use DCS
  - Further legal review is needed to define specifically the availability of capability to other sectors
  - It may be possible to include international satellites and expand satellite DCS use to other platforms.
  - Feasibility of including commercial systems would require modifications to DCS use policies
- Spectrum Regulations
  - Space to space operations are not currently allocated in this band
  - Changes to the spectrum table of allocations, both nationally and internationally will be needed over time.
  - Tests, experiments, and initial use will require an experimental license or authorization

Assessment of Benefits

- Risk Reduction
  - Band already allocated to allow space to Earth transmission for satellite operations
  - Satellites primarily transmit in all directions (omnidirectional antennas)
  - Radiate in the direction of GOES and other DCS receiving satellites
  - radiated energy, aggregated across multiples of these satellites is expected to become a problematic source of RFI to the DCS
  - DCS enable improved control of the radiated energy to work with the other DCS transmitters and minimize interference
  - using DCS will assist in minimizing the risk of interference but will not eliminate it
- Other Benefits to GOES DCS
  - Increased use of the International channels, which are currently underutilized.
  - Low cost enablement of scientific, educational, and development satellite low data rate communications to respective mission centers
  - Ability to enable LEO&A during clustered deployments
  - Projected demand for enabling two-way communications capabilities of the DCS
  - Demonstrated continued efforts by NOAA/NESDIS to facilitate good spectrum stewardship and efforts towards responsible sharing of spectrum resources.

Schedule

The proposed timeline for the first test is::

Phase I Safety Review	3/2/2018
Phase II Safety Review	5/11/2018
Vibration Test	Between 3/16/18 — 5/18/18
Fit Check with ROA	Between 3/16/18 — 5/18/18
Phase III Safety Review	6/29/18
Delivery to NanoRacks	Early July 2018
Delivery to NASA	Late July 2018
Launch	Q3/Q4 2018
Target Deployment	Q4 2018 / Q1 2019

The proposed rough timeline for the second test is:

Development Phase	10/1/2018 – 4/1/2019
Flight Test	TBD – possibly on TES10

Current Status, Activities, & Issues

- Designing DCS transmitter board(s) for hosting on the NASA Ames TechEdSat 8. Working to account for Doppler shift, utilizing hosted GPS receiver data, and power control as needed.
- Designing interface commands, preparing satellite for payload integration and establishing a power source sufficient to support the DCS payload during its transmission cycle.
- Working the DCS use logistics, discussing and coordinating with the DCS user community, providing engineering analysis, and managing project development.

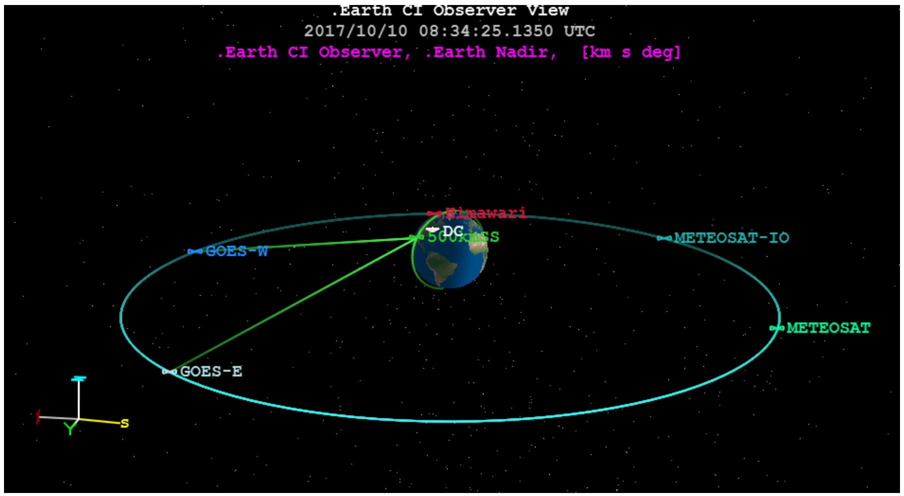
Conclusion

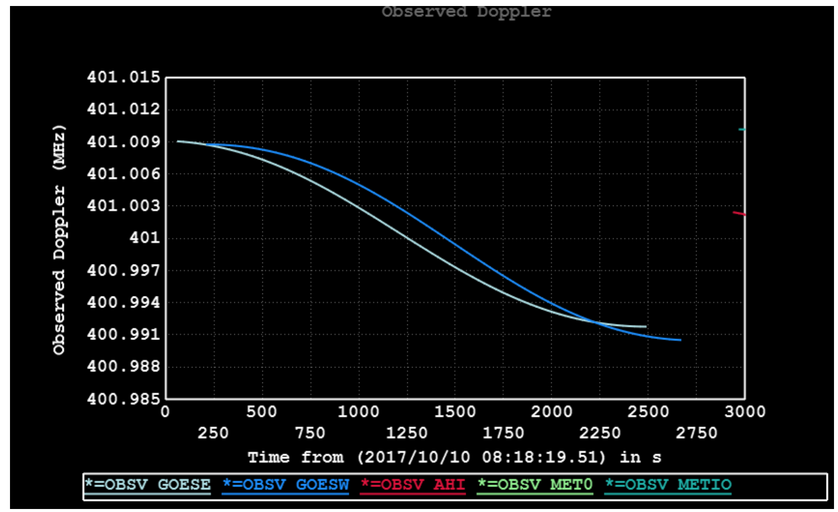
- The 401-402 MHz band is under pressure from smallsat constellation companies to use for their systems
  - NOAA is working with these companies and with the spectrum regulatory authorities, but effective, long-term solutions remain elusive.
  - Satellite use of the DCS system is expected to alleviate some risk and further strengthen the value of protecting the system
- The tiger team did not find any issues that could not be resolved through engineering or policy.
- NOAA OGC is of the opinion that this is feasible from a legal perspective and further demonstrates NOAA’s spectrum sharing support
- We can validate the satellite DCS use concept over the next two years.
  - It can also be used by the international community, thus expanding the availability of DCS satellite use of the international bands
- Development and build cycles are very short. To meet the proposed schedule, NESDIS needs to commit to the project and work quickly to keep the development team focused and functioning effectively.


Questions?
NOAA
NASA

Doppler Correction

LEO tracks to GOES-E, signal also received at GOES-W





$$\Delta f = f_o - f_c = \frac{v \cdot f_c}{c}$$

$$f_o = \frac{v \cdot f_c}{c} + f_c$$

$$f_o = f_c\left(\frac{v}{c} + 1\right)$$

$$f_c = \frac{f_o}{\left(\frac{v}{c} + 1\right)}$$

- Assumes observed frequency within band of DCS Channel 1 (401.701Mhz), carrier frequency corrected for Doppler effect
- Correction is for given pass only